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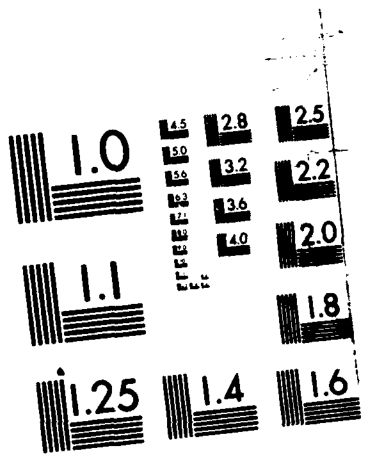

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SYNTHETIC SEISMOGRAMS, GRAPHIC SOFTWARE AND COMPUTER FACILITIES

David W. Simpson

Lamont-Doherty Geological Observatory
of Columbia University
Palisades, New York 10964

May 1985

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September 1984 - May 1985

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This technical report has been reviewed and is approved for publication.

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A SUN-1/100U graphic workstation, which was ~~supplied~~ by DARPA, ~~has been~~ installed in the Seismology Computing Lab~~oratory~~ at Lamont-Doherty, ~~and~~ has become the centerpiece of a digital waveform processing and analysis facility. A local area network (LAN) comprising Ethernet/TCP-IP protocols connects the SUN-1 with the Observatory's pre-existing VAX 11/780 and PDP 11/70 installations. The operating systems on the VAX (VMS) and the PDP (Unix bsd 2.9) were updated and modified to provide support for the full set of Ethernet utilities. The Ethernet LAN is undergoing start-up testing and soon will be fully operational.

While the SUN-1 offers only rudimentary computational power, its state-of-the-art graphic capabilities have enabled us to develop a "quick-look" digital

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cont

data-handling facility. Once the network is fully operational, the resources of the Observatory's other computer laboratories will become available to the SUN-1. The VAX will be used as the network fileserver, peripheral handler, and computational node, while the SUN will be used for the graphic analysis of waveforms and digital images. Preliminary experiments with the network suggest that powerful graphic workstations integrated vertically with file-servers, computational nodes, and supercomputer communication capability provide a flexible, powerful, and productive computational environment for research in seismology and tectonophysics. Keywords: Seismic data processing; Geological observatories.

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INTRODUCTION

The primary purpose of this contract was to integrate a DARPA-supplied Sun workstation with the existing computer facilities available to the Seismology group at Lamont-Doherty. This has been the first step in greatly expanding Lamont-Doherty's capabilities for the collection, storage, retrieval, display and analysis of digital seismic waveform data. The work covered in this contract primarily involved hardware installation and modifications/additions to operating systems to allow direct communication between computers.

Some software development has been done, but this activity is primarily taking place under a new DARPA contract. The main software oriented goals are the development of interactive graphic software for the display and preliminary analysis of digital seismic waveform data and the development of interactive modeling capabilities for more sophisticated waveform analysis.

The funds under the contract provided for the personnel time for the installation of the Sun system and purchase of limited hardware for an Ethernet interface between the Sun and existing computer systems.

NETWORKING

A block diagram showing the existing and proposed developments in the computing network at Lamont-Doherty is shown in Figure 1. Indicated on this figure are those components that have resulted directly from this contract and those that have been provided by the Observatory, primarily as a result of stimulation from this work.

The workstation as provided by DARPA consisted of a SUN-1/100U with an 80 Mbyte disk and a 1600 bpi tape drive. The system had a number of limitations which initially made it difficult to realize its full potential as a seismic analysis workstation. The most critical limitations were the lack of a local printer/plotter, limited disk storage, relatively slow CPU (no arithmetic processor) and differences in graphics primitives and screen size from current Sun models.

The initial step to overcome these limitations was to link the Sun to the PDP 11/70 via uucp at 9600 baud. This provided the Sun with access to the PDP's two Versatec printer/plotters, its disk storage, and its connections with the outside world. The uucp link has been most used for printing and plotting as there is no local printer on the Sun. Uucp's remote execution capabilities have allowed the use of a simple command on the Sun (vpr filename) to combine the file transfer and printing operations. The same is true of Sun graphic screen dumps. The raster files on the Sun are transferred to the PDP for plotting on the Versatecs. With uucp providing the transfer and remote execution, a program to actually write the raster file to the plotter was written locally.

While our original intention was to establish an Ethernet link between the Sun and our Seismology PDP 11/70, we have been able to use this development as leverage to convince the Observatory to provide the funds to begin the installation of a campus-wide Ethernet link, starting with a link between the Observatory's main VAX 11/780 and the Seismology computer facility. The Observatory's VAX operates under the DEC VMS operating system. To facilitate communication with the UNIX-based 11/70 and Sun computers in Seismology, a UNIX emulator, EUNICE, has been installed (with Observatory funds) on the VAX, providing full uucp and Ethernet protocols. A local area Ethernet, a major segment of it using fiber optic cable and again funded primarily with Observatory funds, will connect the Sun, the PDP 11/70 and the VAX 11/780. The VAX archives Lamont-Doherty Geological Observatory's (LDGO's) geophysical data bases and supports extensive peripherals such as image processing hardware, laser printing, and large pen plotters. All these resources will become available to the Sun over the network. The wiring for the connection between the Sun and the PDP has been installed and the software on the PDP is now in the process of being upgraded to allow networking. (We acknowledge substantial assistance from Keith Bostic at CSS and Scott Bradner at Harvard.) The VAX-11/70 link is now operating through uucp at 9600 baud. The VAX will join the full Ethernet network as soon as fiber optic repeaters arrive.

The network will make the CPU power of the VAX easily available to the Seismology computing facility, alleviating the CPU limitations of the Sun-1. The disk storage available to the Sun is also being improved by the purchase, again with Observatory funds, of one 400 Mbyte disk drive. The next step in expanding the network is an additional Sun color workstation and a proposal has been submitted to NSF for this purpose.

SOFTWARE DEVELOPMENT

We are developing an interactive seismic analysis system which can be implemented on a local area network of high-powered graphic work stations. The SUN-1/100U on loan from DARPA has been the cornerstone of this emerging system, as well as a test-bed for software development. In the course of this effort, we have identified four categories of software development tasks:

1. Interactive catalog searches and retrieval of GDSN waveform data: As a designated regional data center, LDGO is a repository for ISC and PDE catalog data, ISC parameter data, and GDSN network-event data. We have developed search algorithms for these data bases, but have been unable to keep most of the catalog information on-line because of disk space limitations. In addition, we have developed interactive routines for the playback of GDSN network-event tapes (Figure 2). We are developing management software to integrate the ISC and PDE catalog data with a catalog of the events contained in the GDSN data base, so that search procedures can be integrated with the waveform data playback.

2. Interactive waveform parameter extraction, and interactive parameter and waveform modelling for studies of source and structure: We have installed interactive parameter extraction software (spex),

provided by Science Horizons (Wang et al., 1983). In addition, we have rewritten an interactive velocity modelling code (originally written by P. Shearer of Scripps Institution of Oceanography) to conform to the SIGGRAPH Core standard, and have installed it on the SUN (Figure 3). This combination of codes gives us the capability, for example, to forward-model travel-time parameters extracted from waveform data bases quickly and nearly automatically. We will expand the capabilities of the velocity-modelling code to include preliminary travel-time inversion and waveform modelling capabilities. The graphics capabilities of the SUN are instrumental to the development of an efficient user interface to these codes.

3. Synthetic seismogram codes and software development systems: While the SUN-1 does not possess a processor with sufficient power to calculate synthetic seismograms for realistic earth models, its multi-window environment and UNIX operating system provide for exceptionally rapid development and debugging. Once debugged, complex codes are uploaded to a faster processor for computation. Results are downloaded to the SUN for graphic analysis (Figure 4). We are implementing an organizational framework for software development that will permit us to keep track of the multitude of codes and revisions produced in a research environment.

4. Interactive graphic routines for plotting 2-D and 3-D geophysical data sets: We have written and installed on the SUN a set of command-format plotting codes for 2-D and 3-D gridded geophysical data. These currently are being debugged. We have also developed the capability, using SUN graphics primitives, to produce publication-quality line and gray-shade plots of 3-D geophysical data (Figure 4). We are evaluating the possibilities of translating these codes into the CORE graphics standard.

Some of these development activities might seem to reproduce the functions of CSS, but we are confident that the software developed at L-DGO will be of interest to CSS. While we recognize the importance of CSS as a national data center, we believe that the development of local data base management capabilities and analytical software will complement, rather than compete with, facilities offered by CSS. Not only will our local capabilities enhance the productivity of our investigators doing research of interest to the DARPA program for treaty verification, but we envisage that the development of local capability integrated vertically with CSS communication capability will expand the usage of CSS facilities by our scientists.

ADDITIONAL ACTIVITIES RELATED TO THIS CONTRACT

Digital topographic data for Soviet Central Asia were requested under this contract for use in comparing topography and seismicity. These data were supplied during May-July 1985. Two hundred cells of $1^\circ \times 1^\circ$ each with 1200 points/degree (appox. 100 m spacing; total of 3×10^8 points) are included in the $10^\circ \times 20^\circ$ area covering the Tien Shan, Pamir, Hindu Kush and Tadjik Depression. These data are now being entered into a format suitable for comparison with the available seismicity data and for analysis with our image processing facility.

The Palisades seismograph station (PAL) at Lamont-Doherty has recently been upgraded to digital recording. The data are collected on a dedicated multibus microprocessor and written continuously to 9 track tape. The tape is first processed on the Sun and then, as necessary, events are transferred to the PDP or VAX for further processing. A program has been written to decode the 9-track tape, which is in LDGO's own format, into CSS 'wfdisk' format and selectively retrieve the events. A second program selectively extracts events to be saved on an archive tape.

REFERENCES

Wang, J., R. M. Rother, V. L. Hutchison, J. H. Alexander, and J. B. Minster, Seismic parameter extraction package, S-Cubed Report #SSS-R-84-6423, 1983.

CHARGES TO 5-22107 (NETWORK RELATED)

1	Fiber optic cable for Ethernet repeater	$1750.00
2	Interlan Ethernet transceivers	580.00
2	DEC Ethernet transceivers	600.00
4	Transceiver cables	304.00
4	Ethernet terminators	75.00
	Tools	253.58
	TOTAL	$3562.58

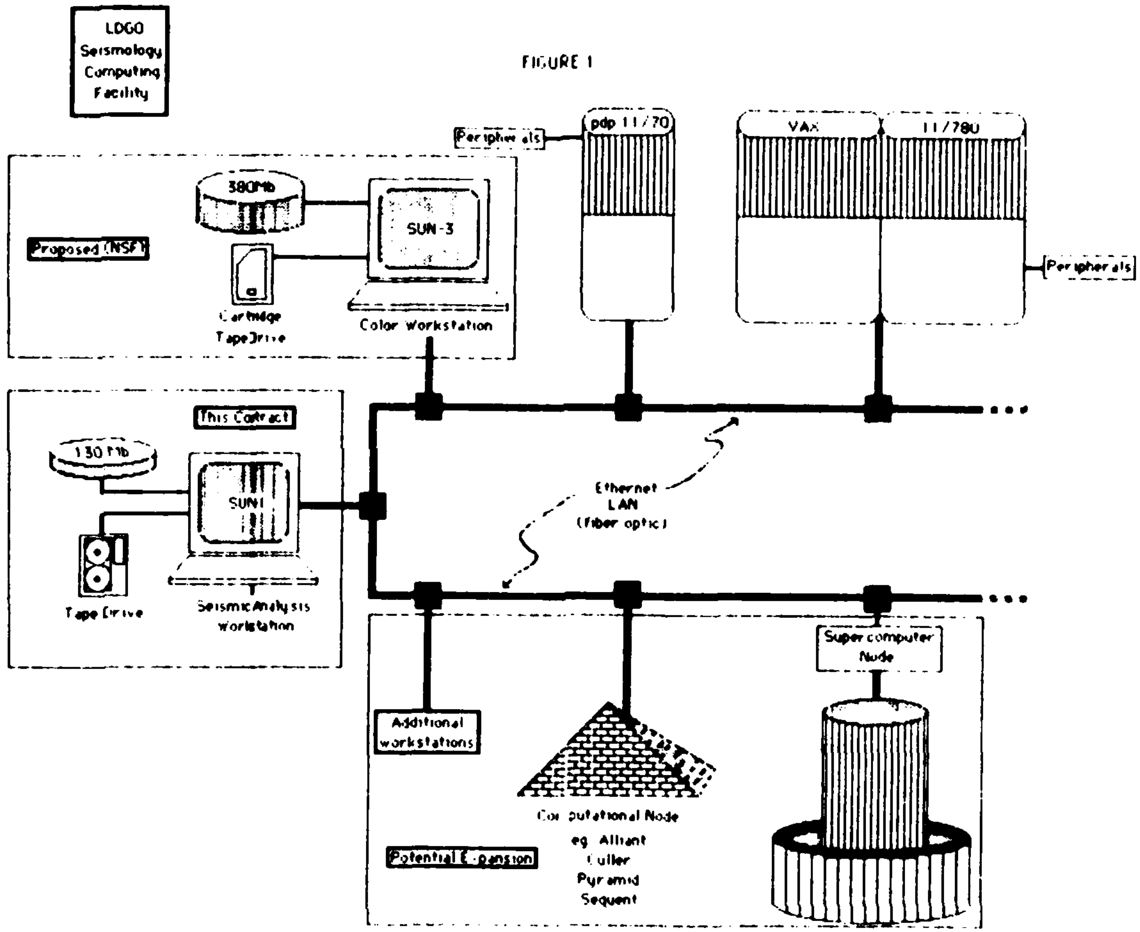

Figure 1. Schematic illustration of the LDGO Seismology Computing Facility currently under development. A fiber-optic Ethernet LAN will connect the Geoscience VAX 11/780 with Seismology's PDP 11/70 and the SUN-1 provided under this contract. Funding for additional SUN-3 high-performance color workstation has been requested from NSF. The Ethernet allows the SUN-1 to access the extensive peripherals resident on the PDP and the VAX. Future additions to the LDGO LAN may comprise additional workstations, a local computational node, and a communications node for the Von Neumann Supercomputer Center.

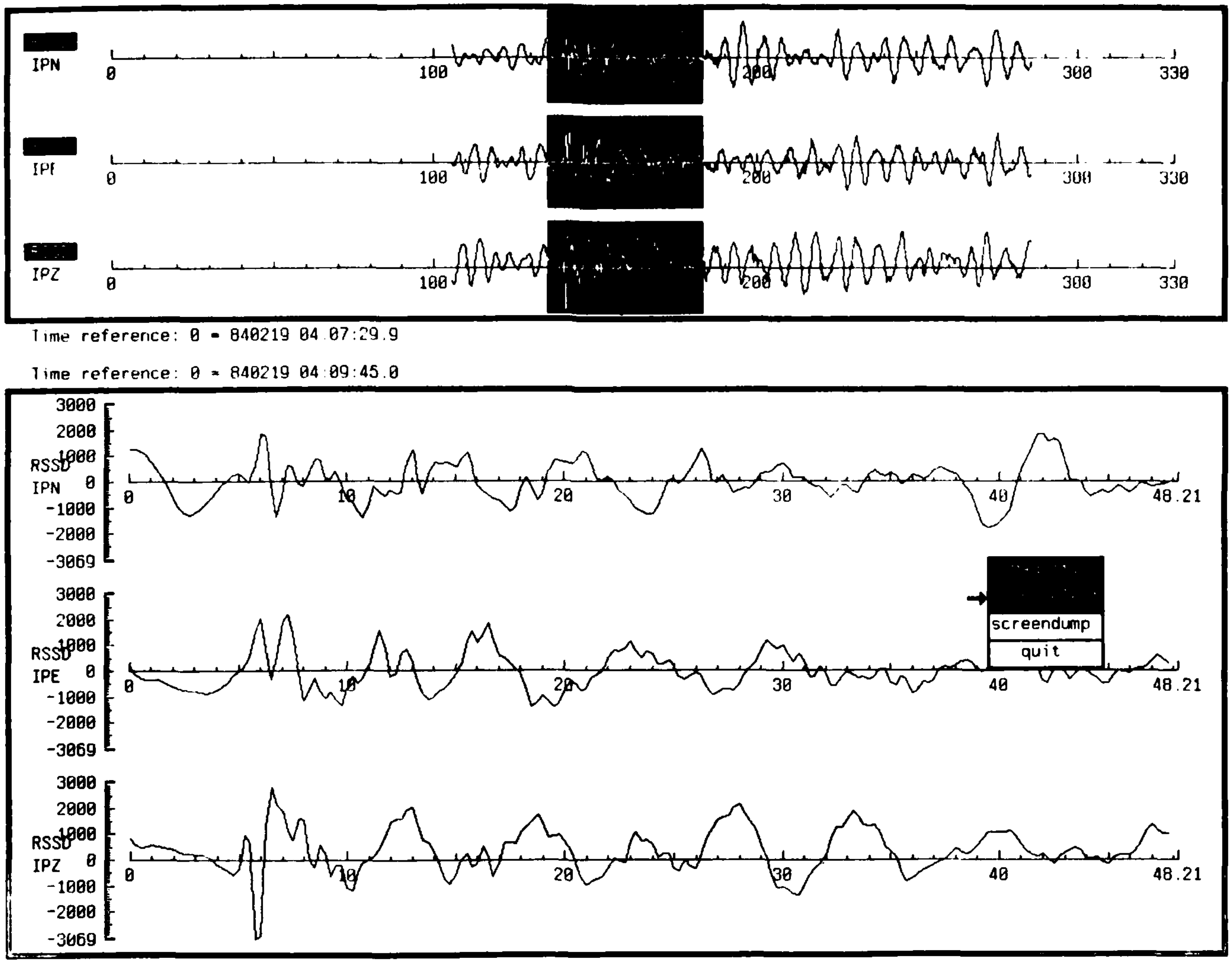

Figure 2. Screen-dumped snapshot of the interactive waveform analysis package developed on the SUN-1 by LDGO staff and students. Selected waveforms are displayed in full in the top window, while selected time-windows are magnified below. The user interface is by means of "pop-up" menus which offer different processing options. The program offers "ports" to external processing procedures which also reside as stand-alone utilities. All graphic software is written in SUN primitives to provide rapid plotting. Other software is written in "C" and uses advanced UNIX programming techniques, such as bi-directional piping, to promote a highly-interactive environment.

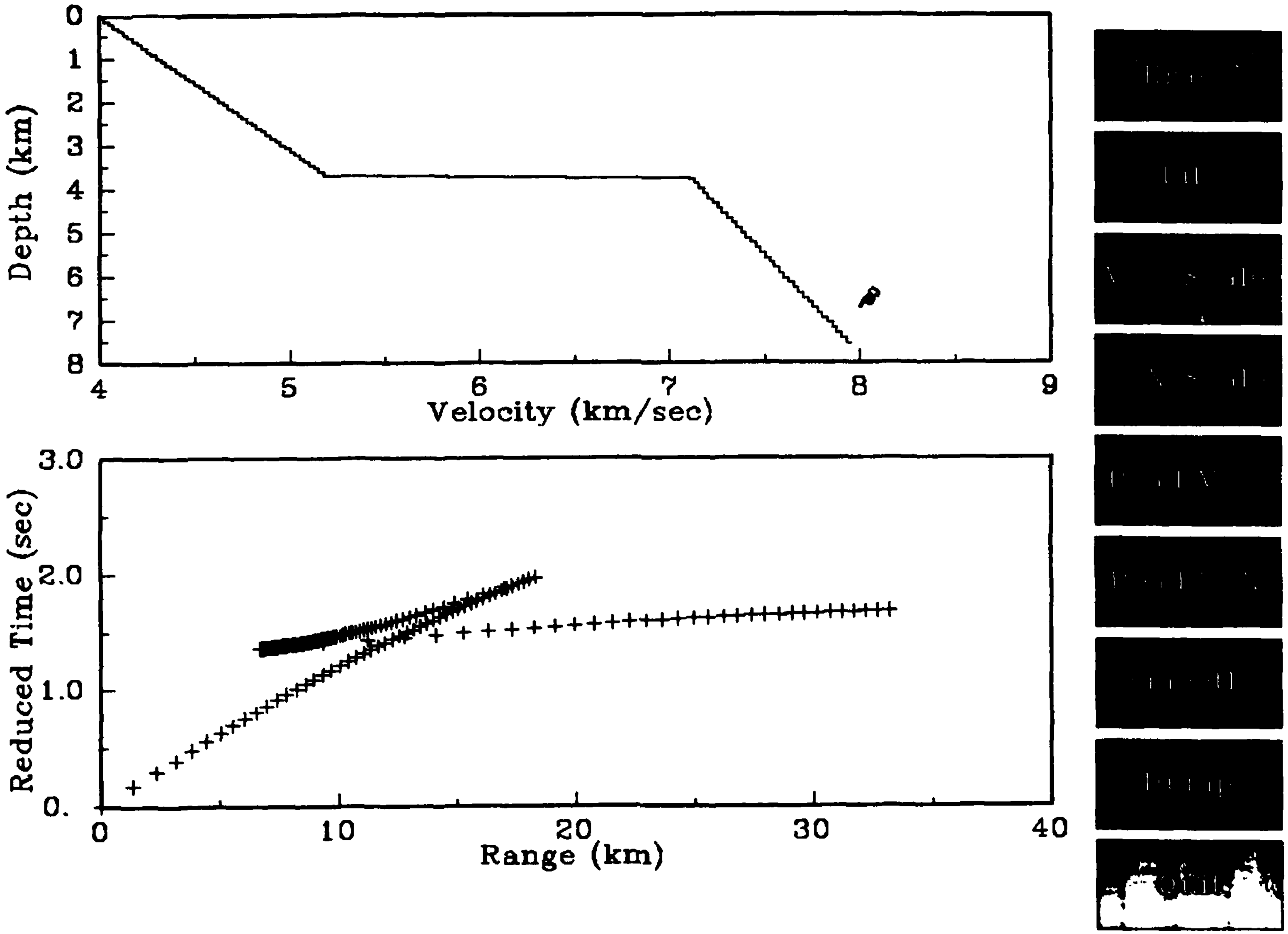

Figure 3. An interactive velocity modelling program, originally conceived and written by P. Shearer of the Scripps Institution of Oceanography. A velocity model is sketched with the mouse in the top window while travel times are plotted below. A bar menu to the right offers several user options. The code, which adheres to the SIGGRAPH CORE standard, is being expanded to include some waveform modelling capability.

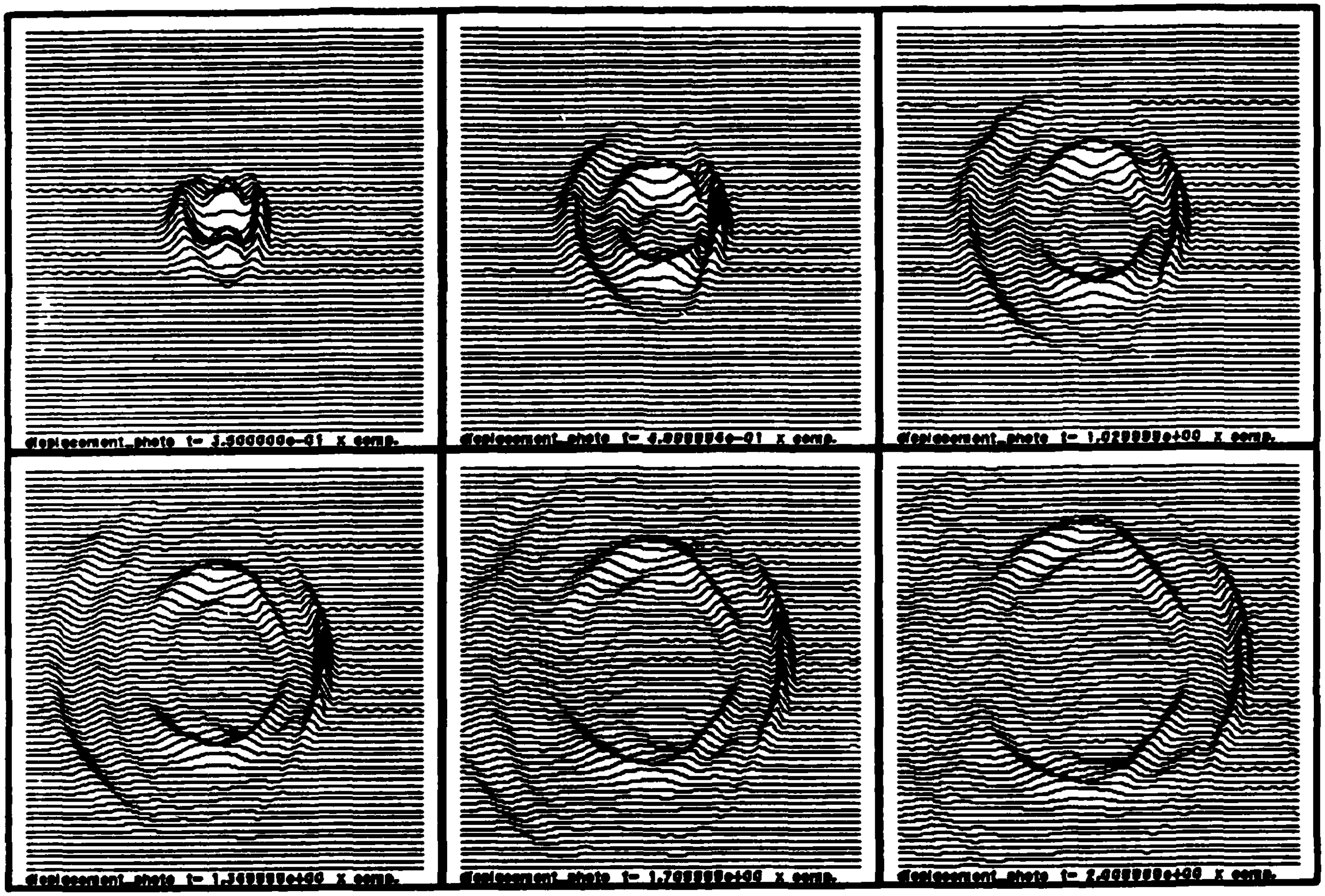

Figure 4. Six time snapshots showing the results of an elastic calculation with non-reflecting boundaries. The medium comprises two homogeneous half-spaces in contact along a vertical plane, the right-hand medium having lower P and S velocities than the left. The initial displacement field was gaussian in the x-component at the center of the grid. The calculations, performed on the SUN-1, include all converted and diffracted phases.

END
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